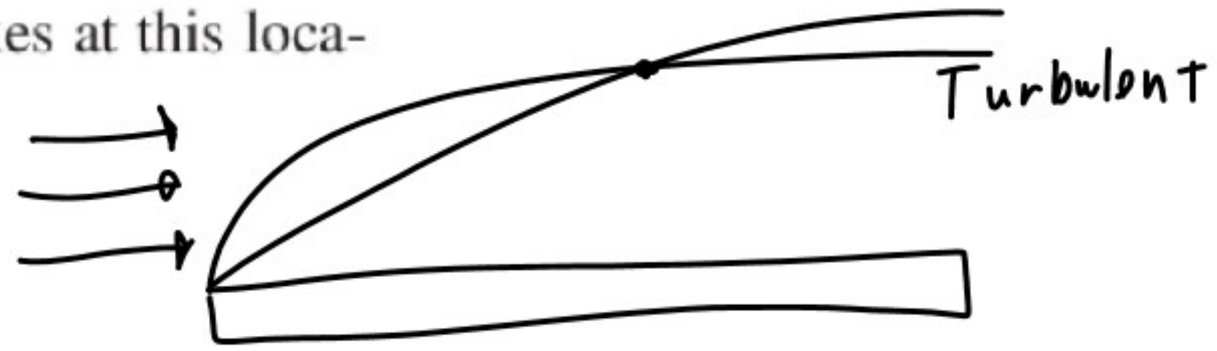
7.11 Consider two cases involving parallel flow of dry air at $V = 1$ m/s, $T_\infty = 45°C$, and atmospheric pressure over an isothermal plate at $T_s = 20°C$. In the first case, $Re_{x,c} = 5 \times 10^5$, while in the second case the flow is tripped to a turbulent state at $x = 0$ m. At what x-location are the thermal boundary layer thicknesses of the two cases equal? What are the local heat fluxes at this location for the two cases?

$$T_f = \frac{T_\infty + T_s}{2} = \frac{45 + 20}{2} = 32.5°C$$



Laminar

$$\delta_t = \frac{5x}{\sqrt{Re_x}} \frac{1}{Pr^{1/3}} = \frac{5}{\sqrt{\frac{u_\infty}{\nu x}}} \frac{1}{Pr^{1/3}}$$

Turbulent

$$\delta_t = 0.37 x \, Re_x^{-1/5} \, Pr^{-1/3}$$

$$0.37 \cancel{\times} Re_x^{-1/5} \cancel{Pr^{-1/3}} = 5 \cancel{\times} Re_x^{-1/2} \cancel{Pr^{-1/3}}$$

$$\frac{Re_x^{-1/5}}{Re_x^{-1/2}} = \frac{5}{0.37}$$

$$Re_x^{-1/5+1/2} = 13.5 = Re_x^{0.3}$$

$$Re_x = 5958$$

$$Re_x = \frac{u_\infty x}{\nu}$$

$$x = \frac{Re_x \nu}{u_\infty} = \frac{5958 \;\; 15.89 \times 10^{-6} \; \frac{m^2}{s}}{1 \; m/s}$$

$$= 0.093 \; m$$

7.28 The boundary layer associated with parallel flow over an isothermal plate may be tripped at any x-location by using a fine wire that is stretched across the width of the plate. Determine the value of the critical Reynolds number $Re_{x,c,op}$ that is associated with the optimal location of the trip wire from the leading edge that will result in maximum heat transfer from the warm plate to the cool fluid.

$$\overline{Nu}_L = (0.037\, Re_L^{4/5} - A)\, Pr^{1/3}$$

$$A = 0.037\, Re_{xc}^{4/5} - 0.664\, Re_{xc}^{1/2}$$

$$\frac{dA}{dRe_{xc}} = 0037\, \frac{4}{5}\, Re_{xc}^{-1/5} - 0.664\, \frac{1}{2}\, Re_{xc}^{-1/2} = 0$$

$$0.037\, \frac{4}{5}\, Re_{xc}^{-1/5} = 0.664\, \frac{1}{2}\, Re_{xc}^{-1/2}$$

$$Re_{xc} = 3158$$